in the development of the Zoological Park and of the serious work of the society, all concerned are to be heartily congratulated on the progress that has been made up to date, and the promise of rapid advance in the near future. A gratifying feature in the year's record was the transference of the New York Aquarium to the management of the society, since, as we are told in the report, this was made spontaneously by the municipality without any suggestion on the part of the governing body. The society has organised the administration of the aquarium on practically the same basis which has been found so effective in the case of the Zoological Park, with a director and council who secure the best expert advice obtainable. As regards the general progress of the park, the report records the completion of a lion house, and the issue of a contract for a building devoted to the exhibition of antelopes. The executive committee states, however, that if the menagerie is to equal the best European institutions of a like nature, even, greater efforts in the way of new buildings must be made in the future.

Judging from the excellent reproductions of photographs with which the report is illustrated, the larger mammals are allotted ample space, and enjoy, whenever practicable, surroundings suitable to their particular requirements. This is well exemplified in the annexed illustration of a group of Barbary wild sheep in the collection.

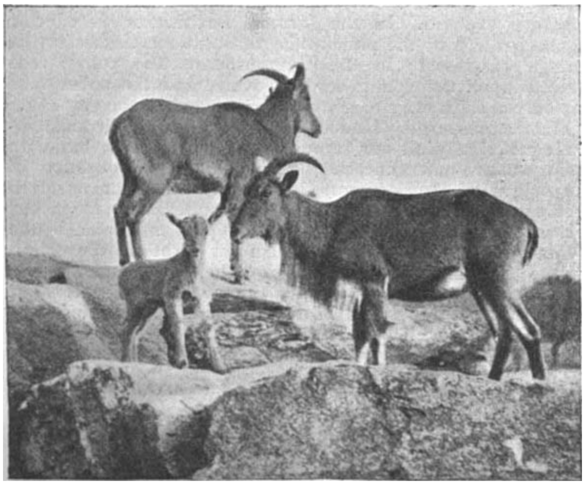

FIG. 1.—A group of Aoudad, or Barbary wild sheep. (From Report of the New York Zoological Society.)

Perhaps the most important part of the society's work, so far, at any rate, as menagerie administration is concerned, is the establishment of a medical department on what it is hoped may be a permanent basis. In the words of the report, "the object of this service is, by systematic observation and record, and by experimental treatment, to extend our knowledge of the care and health of wild animals in captivity, the causes of various diseases, and the means which should be taken for their prevention. This is both humane and part of an economic administration." The establishment includes a well-known medical pathologist, a trained veterinarian, and an expert in microscopic investigation and the preparation of pathological cultures. To the report before us the last-named official contributes two communications of prime importance in regard to menageries, namely, one on the modes of tubercular infection in wild animals in captivity, and a second on cysticerci in wild ruminants. The work of the department in question is therefore already in full swing, and its investigations will doubtless be found of the highest value to menagerie authorities throughout the world. None of us can fail to be pained at the large percentage of ailing animals to be seen in every menagerie, and all will therefore welcome anything that can be done to render such cases less common in the future.

In addition to the aforesaid special papers and the reports of various officials, the volume before us contains other articles of interest. In one of these, for instance, Mr. R. H. Beck gives a graphic account of hunting for giant tortoises in the Galapagos Islands, illustrated by a photograph of these reptiles coming to a pool to drink, and by a second of the mode in which their empty shells are carried on mule-back to the coast. The psychology of birds forms the subject of a communication by Mr. C. W. Beebe, while Mr. R. L. Ditmars discourses on the method of feeding reptiles in captivity, with especial reference to the somewhat forcible measures adopted in the case of a recalcitrant python.

To those who make the study of mammals a speciality, as well as to big game hunters and sportsmen generally, a paper by the secretary, Mr. M. Grant, on caribou, or reindeer, will be of special interest, not only from the excellent account of the various local forms, but from the numerous illustrations by which their distinctive features are displayed. One of these we herewith reproduce, on account of its being taken from an animal in the wild state. Mr. Grant considers that all the American caribou may be divided into two groups, the large and light antlered barren ground group, and the woodland group, distinguished by the short, heavy, and much-branched antlers. The distribution of the various members of these two groups is illustrated in a coloured map. R. L.

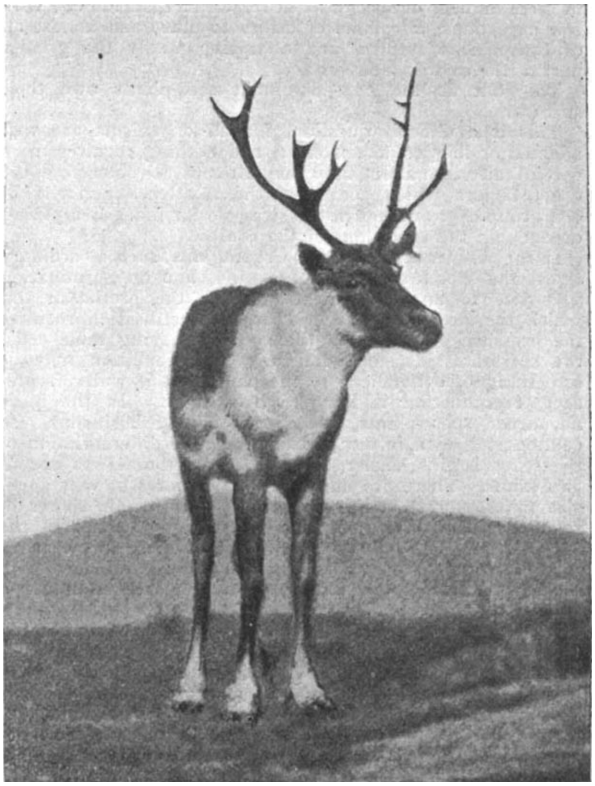

FIG. 2.—Wild Newfoundland Caribou. (From Report of the New York Zoological Society.)

THE ORIGIN OF SEED-BEARING PLANTS.[1]

WHEN Linnæus, in 1735, brought out his famous sexual system of classification, which for so long dominated systematic botany, twenty-three out of his twenty-four classes were occupied by flowering plants, and one only was left for the flowerless plants or Cryptogamia.

As the name "Cryptogamia" indicated, a thick veil of mystery still hung over the reproductive processes of these flowerless plants. When this obscurity became gradually dissipated, with the aid of improved microscopes, by the brilliant researches of Hedwig, Mirbel, Nägeli, Pringsheim, Cohn, Thuret, and above all Hofmeister, and the "Cryptogamia," to quote a phrase of Prof. Sachs's, became the true "Phanerogamia," their relative importance received better recognition. In a recent classification—that of Prof. Warming—out of twenty-three classes no less than eighteen are assigned to Cryptogams.

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[1] Discourse delivered at the Royal Institution on Friday, May 15, by Dr. D. H. Scott, F.R.S.

In spite of our vastly increased knowledge of the Cryptogamia, the flowering plants are still in the majority as regards species. According to a recent census, out of about 175,000 known species of plants, about 100,000 or 4/7 are phanerogamic. For our present purpose we may speak of the flowering plants as the seed-bearing plants or Spermophyta, for at least in recent vegetation the two characters, the grouping of the reproductive leaves in a flower and the formation of a seed, go together, and the latter is the more definite and constant feature. The Cryptogams, such as ferns, mosses, seaweeds, and fungi, may, in contradistinction, be spoken of as the spore-bearing plants or Sporophyta. In the vegetation, then, of the present day, the seed-bearers are enormously predominant, not so much in mere number of species as in importance, including, with few exceptions, all plants of utility to man, and almost all of conspicuous stature, and occupying vastly the greater part of the earth's land surface.

To what do the now dominant seed-plants owe their success?

This is a difficult question, for all organisms are well adapted or they could not exist, and nothing requires more careful discrimination than the attempt to determine the exact factors which constitute the relative superiority of one group over another in the struggle for life. Everything depends on the conditions of the contest.

In the simpler of the higher Cryptogams, such as ordinary ferns, the spores are all of one kind, and on germination give rise to an independent plantlet, the prothallus, on which the sexual organs are borne. Fertilisation requires the presence of water for the actively moving male cells, the spermatozoids, to swim in. This condition may be something of a handicap to the plant, but if water is present, reproduction is fairly well ensured. In the more advanced spore-plants, such as the Selaginellas, so commonly grown in our greenhouses, the differentiation of the sexes begins earlier, for the spores themselves are of two kinds. There are numerous male spores of very small size (microspores) and comparatively few female spores of relatively large size (megaspores). In the group of the water-ferns (Hydropterideæ) only one of these large spores is produced in each spore-sac, which then, if provided with a special envelope, as in Azolla, may closely simulate a seed.

In the microspores, the prothallus is scarcely developed; the spore has practically nothing else to do but to produce the spermatozoids. On the female side, provision has to be made for the nutrition of the embryo, and here there is a comparatively bulky prothallus, though, as compared with that of the ferns, it tends to lose the character of an independent plant, and to become a mere storehouse of food-materials. There are certain obvious advantages in this heterosporous condition. The male spores are kept small for easy dispersal, and can be produced in correspondingly large numbers. The prothallial tissue is economised and only formed where it is wanted, *i.e.* in connection with the egg-cells from which the embryos arise.

The differentiation of microspores and megaspores is, in fact, comparable to that earlier differentiation of minute active spermatozoids, and large stationary ovum, which took place far back in the history of both animals and plants, and laid the foundation of sex.

At the same time the heterosporous arrangement, as we find it in Cryptogams, puts a new obstacle in the way of the successful accomplishment of the act of fertilisation. In order that this may happen it is necessary that the two kinds of spores should germinate together, as well as in the presence of an adequate water supply. The necessary association of the large and small spores is, as a rule, left to chance, the small spores being produced in enormous numbers, so that the chance may be a good one.

In the case of the great cryptogamic trees of the Palæozoic period the difficulty must have been a serious one. We know that their spores often differed in mass in the proportion of at least 100,000 to 1, and when bodies of such diverse weights were scattered by the wind from the tops of lofty trees, the chances must have been enormously against their coming to rest at the same spot. It was perhaps to this difficulty that the series of adaptations leading up to seed-formation owed their first inception.

If the microspores could be brought to the megaspores while the latter were still attached to the parent plant, much greater certainty of their union would be gained, for adaptations would now become possible for catching the small spores and retaining them in position. Some of the Cryptogams now living have got as far as this; the work of an American lady, Miss Lyon, has shown that in some species of Selaginella the microspores and megaspores meet and the spermatozoids are discharged within the sporangium; fertilisation is effected, and even an embryo may develop before the megaspore is shed. In this last respect these Selaginellas go beyond the seed-plants of the Palæozoic period, as we shall presently see. The first advantage, then, to be secured was the occurrence of fertilisation, or rather the bringing together of the two kinds of spore, on the parent plant. This is one of the constant characteristics of the seed-bearing plants; the process is spoken of as *pollination*, for what we call the pollen-grains are nothing but the microspores of the Spermophyta.

We will now see how the process actually goes on in some of the simpler seed-plants of the present day.

The seed-plants, as is well known, are divided into two great classes, the Angiosperms, in which the seeds are enclosed in a seed-vessel, and the Gymnosperms, in which they are exposed. In the former, fertilisation is effected by the growth of the pollen-tube through the tissues of the young seed-vessel; in the Gymnosperms the pollen falls directly upon the young seed or ovule, and the pollen-tube has only a short way to grow before reaching the egg-cell.

The Angiosperms (Monocotyledons and Dicotyledons) include practically all our familiar flowering plants, but with them we are not concerned at present. The question of the origin of Angiosperms is one of the great unsolved problems of botany, but it does not immediately touch our present subject. It is to the simpler seed-plants—the Gymnosperms—that we must turn for light on the origin of the seed-plants as a whole. The Gymnosperms are enormously the more ancient of the two classes, extending back through the whole of the Carboniferous period into the Devonian, while the Angiosperms, so far as we know, only appeared quite late in the Mesozoic period.

The most familiar of the Gymnosperms—the Coniferæ or cone-bearing trees—are themselves too far advanced on the seed-bearing line for our purpose. We will concentrate our attention on a family which, of all living flowering plants, stands nearest to the Cryptogams, namely, the Cycads. This group, not very well known to the non-botanist, but of which a splendid collection will be found in the palm-house at Kew, is now a small one, including nine genera and about seventy species, distributed through the tropical and sub-tropical regions of both the old and new worlds. In habit these plants, which may rise to the stature of small trees, bear some superficial resemblance to palms; the agreement with ferns is, however, much more striking.

In the genus Stangeria from tropical Africa, the leaves bear so close a resemblance to those of some ferns in form and veining that the plant, before its fructification was known, was described by competent botanists as a species of the fern-genus Lomaria.

In all Cycads the male fructifications are in the form of cones; the pollen-sacs are borne in great numbers on the under surface of the scales of the cone. In all the genera but one, the female fructifications are also cones, each scale bearing two large ovules. In the type genus Cycas, however, there is no specialised female cone at all. The fertile leaves are borne in rosettes on the main stem, alternating with zones of the ordinary vegetative leaves.

The fertile leaves are of large size and compound form, and usually each of them bears several ovules, which, whether fertilised or not, grow to a great size, sometimes as big as an egg-plum. They are in some species of a bright red colour, and contrasting with the yellow woolly leaves on which they are borne, are conspicuous and beautiful objects.

In thus bearing its seeds on leaves so little modified, and springing like the ordinary leaves from the main stem, Cycas is the most fern-like genus of flowering plants.

The ovule, at the time when pollination takes place, is about the size of a small hazel nut. It consists of an outer envelope and a central body, the two being closely joined together, except towards the top, where the envelope leaves a narrow passage open, leading down to the central body. The apex of the latter becomes excavated into a hollow pit—the pollen chamber—a feature almost peculiar to Cycads amongst *living* plants, discovered by our countryman Griffith so long ago as 1854, though the credit is often wrongly given to later French or German investigators.

The pollen, blown by the wind or possibly conveyed by insects, is received in the opening of the envelope by a drop of gummy substance, and as this evaporates the pollen-grains are drawn down through the narrow passage into the pollen chamber below. There each grain anchors itself by sending out a tube into the neighbouring tissue of the ovule. Thus pollination is accomplished. Fertilisation, *i.e.* the actual union of the male and female cells, takes place some months later, when the ovule, now to all external appearance a seed, has reached its full size. In the meantime, the single megaspore or embryo-sac, embedded in the tissue of the central body of the seed, has grown to enormous dimensions—filled itself with prothallus and developed the egg-cells at its upper end, which are so large as to be easily seen with the naked eye.

The pollen-grain behaves like a cryptogamic microspore and produces two large spermatozoids, each with a spiral band bearing numerous cilia—the organs of motion. The pollen-tube becomes distended with water, bursts, and sets free the sluggishly moving spermatozoids, which by aid of the water discharged from the pollen-tubes are able to swim to the egg-cells and effect fertilisation.

This remarkable process, first discovered in 1896 by two Japanese botanists, Ikeno and Hirase, and independently in 1897 by the American Webber, occurs not only in the Cycads, but also in that strange plant the maiden-hair tree, Ginkgo, a form now completely isolated, certainly rare in a wild state, and said to have been only saved from extinction by cultivation around Buddhist temples in China and Japan, but which has a long geological history.

The cycadean method of fertilisation holds exactly the middle place between the purely cryptogamic process, where the active male cells accomplish the whole journey to the egg by their own exertions, and the method typical of seed-plants, where these cells are little more than mere passengers carried along by the growth of the pollen-tube.

The adaptations, which in the Cycads allow of pollination and fertilisation on the plant, are chiefly three :—

(1) The envelope of the seed with its narrow opening down which the pollen-grains are guided.

(2) The pollen-chamber below in which they are received.

(3) The pollen-tube which, however, plays a somewhat less important part here than in the higher flowering plants, and in the Palæozoic allies of the Cycads may perhaps have been dispensed with altogether.

There are, however, other points in which the ovule of a Cycad differs from the spore-sac of a Cryptogam. Not only is the megaspore solitary—that is a condition already reached among the water-ferns—but it is firmly embedded in the surrounding tissue. It is no longer a mere spore destined to be shed, but remains throughout an integral part of the ovule, while the ovule ripens into a seed and ultimately germinates. Thus the whole development of the prothallus takes place within the seed, and this requires special methods of food-supply, involving a complexity of structure far beyond that of any cryptogamic spore-sac. When the time for dispersal comes, the seed is shed as a whole.

There is, however, another character commonly regarded as essential to the definition of a seed; a seed should contain an embryo. This implies that, after the egg-cell has been fertilised, the young plant develops to a certain extent while still within the seed, and before it is shed. In the ripe seed the embryo passes into a resting stage, and only resumes its development when the seed begins to germinate and the embryo becomes a seedling. Usually, too, the ripening of the seed itself is dependent on the development of the embryo; if there is no fertilisation there is no true seed, only an abortive ovule.

In the Cycads this is not the case; the ovule ripens into a full-sized and apparently normal seed, even if fertilisation has failed. In our hot-houses Cycads are seldom fertilised; yet the conspicuous scarlet seeds of *Cycas revoluta*, or the crimson seeds of Encephalartos, are familiar objects to many Kew visitors. Further, the degree of development of the embryo at the time the seed is shed is very inconstant; sometimes, although fertilisation has taken place, the embryo is scarcely to be detected.

The definite resting stage of the young plant in the dry seed, so characteristic of the higher Phanerogams, is unknown to these primitive seed-bearers, the Cycads and the maidenhair-tree. The same appears to hold good for the seeds found in the Palæozoic rocks. Such seeds are common in certain localities, as in the Coal-measures of central France, and to a less degree in our own coal-beds. In petrified specimens the structure is often beautifully preserved, yet in no single case has a Palæozoic seed been found to contain an embryo. It is not merely a matter of preservation, for that is not unfrequently so good that the delicate egg-cells can still be recognised. Thus there is no known "seed" of Palæozoic age which, according to current definitions, strictly deserves the name. Technically, the term "ovule" would be more appropriate, but the obvious maturity of the integument makes the word "seed" seem more natural. So far the case is parallel to that of our recent Cycads or the maidenhair-tree.

It is, of course, possible that any day we may light on some Palæozoic seed with an embryo; it may be that the specimens hitherto found were all unfertilised, though the frequent presence of pollen-grains in the pollen-chamber makes this explanation unlikely. It seems not improbable that the development of an embryo in the ripening seed was a later device—that in the older seed-plants the period of rest came immediately after fertilisation, and that the growth of the embryo, when once started, went on rapidly and continuously to germination. In that case a seed with a recognisable embryo would rarely be preserved.

We are now in a position to see what are the chief advantages gained by a plant in adopting the seed-habit; they are :—

(1) Pollination on the parent plant, and consequently greater certainty in bringing together the two kinds of spore.

(2) Fertilisation either on the plant or at least within the sporangium, giving greater certainty of success, and protection at a critical moment.

(3) Protection of the young prothallus from external dangers.

(4) A secure water-supply during its growth.

(5) Similar protective and nutritive advantages for the young plant developed from the egg-cell.

This last end, however, was very probably not yet fully attained in the earlier seed-bearing plants.

We may now go on to consider our main subject—the historical question, from what group of spore-bearing plants were the seed-plants derived?

One thing is plain; the stage of heterospory was the immediate precursor of seed-formation, and it was from some group of Cryptogams producing spores of two kinds that the seed-plants sprang. Such heterosporous groups are, however, known in three of the main phyla of the higher Cryptogams.

In the Lycopod series we have, among their living representatives, pronounced heterospory in Selaginella and Isoetes; among the Palæozoic Lycopods it was commoner still. Within the class of the ferns we have the heterosporous water-ferns. In the third series, that of the horsetails, we have, it is true, only homosporous forms now living, but in Palæozoic times a well-marked differentiation of micro- and megaspores was attained, though less extreme than in the other two lines.

So far, therefore, there is no reason why the early seed-plants might not have had family relations with any of these great cryptogamic classes, and, as a matter of fact, all three lines have been championed by one botanist or another as the probable ancestors of the seed-plants.

The horsetail stock, though it attained an extraordinary development, shows no further sign of transition towards the higher plants.

The case for the Lycopods is stronger, and, indeed, they were long the "favourites," and were commonly regarded as lying nearest the true line of spermophytic descent. This idea was specially based on the mode of development of the spore-sacs, which has much in common with that of the pollen-sacs and ovules of Phanerogams, and this, combined with the occurrence of well-marked heterospory in some genera, appeared to point to a relationship. But the former character (the development of the spore-sac from a group of cells instead of from a single one) is now known to be common to certain ferns, and to just those ferns (the Marattiaceæ, &c.) which prove to be the most ancient, so that this argument has lost its weight. It has lately been found, indeed, that some of the Carboniferous Lycopods produced seed-like organs, presenting the most striking analogies with true seeds, but the plants which bore them were in all other respects Lycopods pure and simple, and the case appears to have been one of homoplastic modification. There is no indication, as yet, of any forms really transitional between the Lycopods and the Spermophyta.

The one line which, so far, has yielded truly intermediate types is that of the ferns.

Among recent plants, the Cycads, as we have seen, offer some points of agreement with ferns, sufficient to have led certain distinguished botanists, for example Sachs and Warming, strongly to maintain their fern-ancestry. The chief points of agreement are:—

(1) The fern-like foliage in some Cycads, and in many the mode of folding of the leaflets in the bud.

(2) The arrangement of the pollen-sacs in groups on the underside of the cone-scales, like that of the spore-sacs of ferns on the underside of the leaves.

(3) The carpels or fertile leaves of Cycas, which, though bearing true seeds, are more like fertile fern-fronds than any other reproductive leaves.

By themselves, these characters, though suggestive, would be inconclusive; the anatomy is not directly comparable with that of any living ferns.

What, then, do we know of the history of this family in past times? The Cycads are now a small and isolated group; in the Mesozoic period, from the Trias to the Lower Cretaceous, they were one of the dominant types of vegetation, and spread all over the world. Of the fossil species recorded from the Oolite of the Yorkshire coast and from the Wealden of the south of England, one-third are referred to Cycads, and they were equally abundant in the Mesozoic floras of North America, India, and other countries. If they existed in the same proportion now as then, they would have about 35,000 species instead of 70! The Cycads of the Mesozoic, however, were not, as they are now, a single family, but a great class (the Cycadophyta of Nathorst) embracing very diverse types, often with organs of reproduction widely different from those of their surviving relatives, and showing a certain parallelism with angiospermous fructifications. But with all this there was on the whole a remarkable uniformity in habit, just as we find a general similarity in outward characters among so many dicotyledonous trees of the present day, though belonging to the most diverse families.

In the Mesozoic rocks we also find a certain number of plants (known only from their foliage) as to which it remains doubtful whether they belonged to Cycads or ferns, or to some intermediate group.

Besides the Cycadophyta, seed-plants were represented in Mesozoic days by a great number of Coniferæ, more or less allied to those still living, and by various forms akin to the maidenhair-tree, perhaps the more ancient type surviving in the recent flora.

When we go further back, to the Palæozoic rocks, it is only in their uppermost strata that we find forms clearly referable to Cycads or Conifers.

The best known seed-bearing plants of the older rocks are those of the family Cordaiteæ, which stretches back to the Devonian. They were tall, branched trees, bearing great simple leaves, sometimes a yard long. The anatomy of stem and root resembled that of an Araucarian Conifer, but the leaves had just the structure of the leaflets of a Cycad. Male and female flowers were borne in little spikes or catkins, and may best be compared with those of the maidenhair-tree. The seeds, of which the structure is known, closely resemble those of that plant, or of recent Cycads.

The Cordaiteæ, however, ancient as they are, were already pronounced gymnospermous seed-plants—by themselves they give no direct clue to the origin of Spermophyta. We must look elsewhere for the key to our main problem.

The vast number and variety of fern-like remains throughout the Palæozoic strata, wherever land-plants are known, is familiar to all. Almost every form of recent fern-frond can be matched from the impressions in the Carboniferous and Devonian rocks. A considerable number of these fossil fern-fronds are known to have really belonged to ferns, for typical fern-fructifications are found upon them. An experienced collector of Coal-measure plants, Mr. Hemingway, once told me that he reckoned on finding about 20 per cent. of the specimens of any true fossil fern in the fertile state. When, therefore, a common fossil fern-frond (so-called) is *never* found fertile, a strong suspicion is awakened that the plant must have had some kind of fructification other than that of an ordinary fern. This is the case with a surprisingly large proportion of the Palæozoic plants commonly described as ferns, and holds good of certain entire "genera"; the important genera Alethopteris, Neuropteris, Mariopteris, Callipteris, Tæniopteris, and others, have never yet been found, in any of their species, with fertile fronds, if we except one or two specimens so questionable and obscure that no conclusion can be drawn from them. It is probably under the mark to say that one-third of the so-called ferns of Palæozoic age afford no evidence from fructification that they were really ferns, as we now define them.

The absence of recognisable fertile fronds may, it is true, be partly accounted for by dimorphism. Many ferns, both recent and fossil, bear their reproductive organs on modified portions of the frond, or even on special fronds, very different from the vegetative foliage. Fossil remains are usually fragmentary, and when the sterile and fertile fronds are found isolated, there may be nothing to show that the one belonged to the other. But, allowing for this, there are very many "fern-fronds" which offer no evidence, even from association, of any fern-like fructification, while the fructifications actually associated with them are often anything but fern-like. There are, in fact, a number of unassigned seeds from the Coal-measures, some of which are commonly associated with certain of the quasi-ferns of which we are speaking.

On the whole, however, we have, up to this point, had before us merely negative evidence, indicating that many of the leaves, so familiar to palæobotanists, classed on account of their form and veining as fern-fronds may really have belonged to some group different from the true ferns. Negative evidence is notoriously weak; at most it only justifies us in taking up a position of philosophic doubt, though in this case it was enough to induce the distinguished Austrian palæobotanist Stur to suspect that the genera Alethopteris, Neuropteris, and others were not ferns, but Cycads.

During the last thirty years, however, positive evidence has been accumulating proving that certain of the fern-like Palæozoic plants were at any rate something distinct from true ferns, as we now know them. This evidence is derived from a study of the anatomical structure, which in Cycads and ferns, as they now exist, is sufficiently different to prevent any possible confusion between the two groups. A single section from the leaf-stalk of the fern-like Cycad Stangeria would be enough to show that it is a true Cycad and no fern, and conversely, a single section from the frond of Lomaria, with which Stangeria was once confused, would show it to be a true fern and not a Cycad.

A common Coal-measure plant, named *Lyginodendron Oldhamium*, was one of the first of the Palæozoic quasi-ferns to be examined anatomically. We owe this work, like so many other great advances in fossil botany, to the late Prof. Williamson, who thus led the way to the solution of the problem before us.

Externally, the plant is wholly fern-like; its characteristic highly compound foliage is that of a Sphenopteris (*S. Höninghausi*) with a Davallia-like habit. The large fronds were borne, at intervals, on a somewhat slender stem, which rooted freely. The slender proportions and the presence of spines everywhere, on leaf and stem, suggest that the plant may have been a scrambling climber like *Davallia aculeata*, for example, among recent ferns.

The structure of all the vegetative parts of the plant, stem, leaf, and root, is known as perfectly, perhaps, as in any plant now living. The leaves turn out to be true "fern-fronds" in structure as well as in external aspect. The vascular bundle traversing the petiole, for example, is of the "concentric" type characteristic of ferns, and any differences there may be are in details only.

A section of the stem, however, bears at first sight no resemblance to that of a fern; outside the pith we find, in all mature specimens, a broad zone of wood and bast with its cells arranged regularly in radial series, like that of an ordinary "exogenous" tree, and in detail approaching especially the cycadean structure. At the border of the pith there are distinct strands of wood, and this region, which was laid down before the radially arranged zone, recalls the structure of an Osmunda. The bundles in the cortex of the stem, on their way out to the leaves, have, in this part of their course, exactly the structure of the strands in the leaf-stalk of a Cycad—a structure found, in this form, in no other living plants.

The roots, when young, resembled those of certain ferns (Marattiaceæ), but as they grew older they also formed radially arranged wood and bast like the roots of Gymnosperms.

On the ground of this remarkable combination of structural characters, it was inferred that Lyginodendron could not have been a true fern, but must have occupied a position intermediate between the ferns and the cycadean type of Gymnosperms.

A similar association of diverse anatomical characters has now been proved to exist in various other quasi-ferns of Palæozoic age. In Heterangium, for example, also investigated by Williamson, leaves and roots resemble those of the previous genus, but the stem is more obviously fern-like, agreeing in its earlier stages with that of a Gleichenia, but acquiring, with advancing age, a zone of secondary wood and bast of the cycadean type. This plant likewise bore foliage of the Sphenopteris form (*S. elegans*).

In Medullosa, on the other hand, to which the Alethopteris and Neuropteris foliage belonged, the original ground-plan of the tissues in the stem is like that of a complex fern, but the structure of leaves and roots, and the secondary structure of the stem itself, is almost purely cycadean. We might continue the list much further. Wherever one of these quasi-ferns has been examined anatomically, a similar combination of characters has been found. It may be pointed out in passing that, while many of these intermediate forms lead on towards the Cycadophyta themselves, others approach more nearly to the extinct family Cordaiteæ, and indicate that they also, though so different from ferns in habit, may yet have sprung from the same stock.

But so far the positive evidence has been wholly anatomical, and botanists are not yet altogether in agreement as to the value of anatomical characters. The anatomist very naturally thinks that there is nothing like anatomy, but the pure systematist will not be satisfied without the characters on which he has been accustomed to rely, and his faith in which has been so amply justified, those, namely, drawn from the reproductive organs. Darwin, however, who neglected nothing, was fully alive to the importance of anatomical evidence; he expresses his interest in an anatomical character in an amusing way in one of his lately published letters (1861), saying, "The destiny of the whole human race is as nothing compared to the course of vessels in Orchids!"

Until the present year, we had no satisfactory knowledge of the fructification in any one of the Cycadofilices, as we now call them, of the Palæozoic period. There is, it is true, some reason to believe that a form of fructification with long tufted spore-sacs belonged to Lyginodendron, but we know nothing as yet as to the details—it may prove to represent the male reproductive organs of the plant. Among the unidentified seeds of the Coal-measures, there are some—the great seeds known as Trigonocarpon—which are not only associated with Medullosa, but which show a certain structural resemblance to some of its tissues. But still the indications were slight—so slight that Prof. Zeiller, of Paris, than whom there is no higher authority, has recently expressed a doubt whether these Cycadofilices were, after all, anything more than a peculiar group of ferns.

Within the last few months, however, an altogether new light has fallen on our subject. Among the seeds discovered by Williamson in the English Coal-measures were three species which he placed in his genus Lagenostoma. These, as we shall see, are characteristic seeds of complex structure. One of them, named *L. Lomaxi* by Williamson, though not described by him, has lately been reinvestigated, in the first instance by my friend Prof. F. W. Oliver (see NATURE, June 4). The great peculiarity about it is that the seed itself was borne in a little calyx-like cup, fitting loosely round it, just as a hazel nut is borne in its husk. The cup, or cupule, which is deeply lobed, bears very peculiar glandular bodies, usually with a short thick stalk and a round head which is empty, as if the secretory tissue had broken down. These glands, on the cupule of the seed, have been found to agree exactly in dimensions, form, and structure with the glands borne on the leaves and stems of the particular form of *Lyginodendron Oldhamium* with which the seeds are associated.

Suppose that in some tropical forest where the trees were too lofty for their leaves and fruits to be reached, seeds and leaves and twigs were found scattered together on the ground, and that they all proved to bear exactly similar glandular outgrowths of a kind unknown elsewhere. Suppose, further, that the structure of the envelope of the seed turned out to agree in other respects with that of the vegetative fragments, should we hesitate to conclude that the seeds belonged to the same plants as the leaves and twigs, though we had never seen them actually in connection? Such is the argument with regard to the relation of the seed Lagenostoma to the plant Lyginodendron. Short of finding the vegetative and reproductive organs in continuity, the proof is as strong as it can be, and I think we need not hesitate to conclude that the one belonged to the other.

But, if this be so, the question as to the nature of the Palæozoic Cycadofilices is settled, at least as regards one member of the group. Lyginodendron was already a seed-bearing plant. The seeds are highly organised, and, broadly speaking, of the cycadean type. The integument and central body of the seed are closely joined to near the tip and along the line of junction run the strands which conveyed the water-supply. The upper part of the integument has a curious chambered structure—the central body terminates in a large pollen-chamber of peculiar bell-shaped form, in which the pollen-grains are sometimes found. The neck of the pollen-chamber fits into the opening of the integument and reaches the surface. The centre of the seed is occupied by the large megaspore or embryo-sac, in which remains of prothallial tissue can sometimes be detected. The seed, in fact, is as highly differentiated as any seed of its period, lacking only an embryo, as do all its contemporaries.

But if Lyginodendron, with all its fern-like characters, was thus a true seed-plant, we cannot doubt that other quasi-ferns of that period, exhibiting a similar combination of characters, had also entered the ranks of the Spermophyta, and we may confidently expect that, one by one, many of the as yet unowned Palæozoic seeds will be traced to their fern-like possessors.

Further positive indications of this are already presenting themselves. For example, there is a specimen in the British Museum collection showing a cast of a branched rachis accompanied by a multitude of ribbed seeds, many of which are in clear connection with the rachis itself. At one place we see a leaflet of *Sphenopteris obtusiloba*, a well-known Coal-measure "fern," and everything indicates that we have here the fertile, seed-bearing rachis of that species. There are other specimens which point in the same direction, and now that the eyes of collectors are opened to the possibility of their so-called "fern-fronds" bearing seeds—an idea which before seemed too improbable to be entertained—more of such specimens will doubtless find their way into our museums.

The present position, then, of our question is this. Some, probably many, of the fern-like plants of Palæozoic age bore seeds of the same general structure as those of the Cycads among living Gymnosperms. The plants in question were not merely fern-like; their anatomical structure proves them to have had so much in common with true ferns that there can be no doubt of their affinity with them. In fact, apart from the newly discovered seeds, these plants, for the most part, show a balance of characters on the fern side.

The evidence thus points unmistakably to the conclusion that the Cycadophyta—the most primitive of the seed-plants—sprang from the fern stock. Thus the origin of the great mass of cycadean forms which overspread the world during the Mesozoic epoch is accounted for—they were doubtless derived from the more primitive Cycad-ferns of the preceding Palæozoic age, and through them from some early filicinean ancestry. The first divergence from this original cryptogamic stock must have occurred very far back; the seeds of Lyginodendron and other Carboniferous seeds referable to the Cycadofilices are, as we have seen, already highly organised, and the stages of their evolution from the cryptogamic sporangium are still to be discovered.

The origin of the seed-plants from the fern phylum will probably prove to hold good for other groups besides the Cycadophyta. The great Palæozoic family Cordaiteæ combines the characters of Cycads and Coniferæ, and at the same time shares certain of those anatomical features which first betrayed the true nature of the Cycadofilices. There is thus a strong presumption that the Cycadophyta, the Cordaiteæ, and the Coniferæ themselves had a common origin, or at least that they all sprang, directly or indirectly, from the great plexus of modified ferns which played so large a part in Palæozoic vegetation.

Hence, so far as the gymnospermous seed-plants are concerned, we are led to the conclusion that they were derived, at a very early period, from the fern stock. The following up of the clue, which, as I believe, we have now grasped, will afford a pursuit of the utmost interest and promise.

But the other great problem—the origin of the angiospermous seed-plants, which are now supreme in the vegetable world—is as yet untouched. And so, though real progress has been made, it will be long before we can hope for a complete answer to the question which we have had before us.

THE GOVERNMENT LABORATORY.

THE report of Dr. T. E. Thorpe, F.R.S., upon the work of the Government Laboratory for the year ended March 31, 1903, with appendices, has now been published, and the following extracts from it are of interest.

It appears from the report that the descriptions of imports as given in merchants' entries are often erratic, and give no clue whatever to the real nature of the goods. For example, crushed bones were entered as "semolina," gingerbread as "paints," sodium peroxide as "fancy goods," varnish as "iron goods," whilst "machinery" and "razor strops" turned out to be tobacco fumigating powder and sugar-coated pills respectively.

Many preparations containing spirit are liable to duty also in respect of other ingredients. Soaps, for example, may contain cocoa-butter, spirit and sugar, the latter being frequently used as a cheap substitute for glycerine. Blacking and polishes are examined for sugar or molasses; confectionery for sugar and chocolate; and essences for dutiable tariff articles, in addition to spirit, such as acetic and butyric ether, used for flavouring purposes.

During the year 1173 samples of beer, wort, and brewing materials were tested for the presence of arsenic, the great majority of which were either quite free from that impurity or contained only traces; but in 44 instances the amount was so notable that the brewers were informed in the case of materials that they should not be used, and in the case of wort or beer that it should not be sent into consumption. The largest quantity of arsenious oxide found was, in malt, 1/50th of a grain per pound, in glucose, 1/40th of a grain per pound, in wort, 1/36th of a grain per gallon, and in water-softening material, 7/10ths of a grain per gallon.

No imported sample of butter has been reported as adulterated during the year. Boric acid preservative was present in 98 per cent. of the samples of butter from Australia and Belgium, 86 per cent. of the French samples, 78 per cent. of those from New Zealand, 77 per cent. of the South American samples, 45 per cent. of those from Holland, and 43 per cent. of the samples from the United States. Sixteen per cent. of the Canadian samples contained this preservative. There has been a decrease in the proportion of samples containing boric preservative from 36·3 per cent. in 1902 to 33·5 per cent. in 1903, for which the samples from Holland are chiefly responsible.

Among articles submitted by manufacturers to the Government Laboratory was a filter which was required to deliver a sterile filtrate, but on examination was found to permit the passage of unfiltered water into the reservoir to which only filtered water was supposed to gain access. This is a danger to which insufficient attention appears to be paid by both manufacturers and users of filters. The inefficiency of many of the old filters was long since established, and as a result improvement was effected in the filtering substance, so as to secure that the water passing through should be free from all micro-organisms. In consequence of the precautions necessary where biological investigations are made, it is to be feared that in some instances, when testing the sterility of the filtrate, the filtering cylinders, cones, or candles, have been examined apart from the filter cases in which they are ordinarily fixed, and no subsequent test has been made of the filter as a whole, with its parts fitted together as in common use. Where this is so it is, of course, possible that though the filtering cylinder itself may be entirely satisfactory, its whole value may be destroyed by a faulty connection.

Among work undertaken for the Home Office was an investigation of the character of the products of combustion in gas and oil stoves. It was desired to ascertain whether along with the main products of complete combustion there was an appreciable production of carbon monoxide and acetylene. Five of the best known stoves—three gas and two oil—were experimented with, and, as a result, it was found after the stoves had been alight for some time (1) that no acetylene was produced by any of the stoves, and (2) that a small amount of carbon monoxide was a regular constituent of the products of combustion of all the stoves, the actual quantity per hour's combustion being, for the gas stoves 0·0024, 0·0048 and 0·0480 cubic foot, and for the oil stoves 0·023 and 0·032 cubic foot.

Of the gas stoves, the first two results quoted were from stoves of different type, the first being of the argand class and burning with a luminous flame, whilst in the second the burners were of the Bunsen type, and the flame impinged on skeleton non-combustible fuel. The production of carbon monoxide is greater in the oil stoves than in two out of the three gas stoves, and it emphasises the necessity of carrying off the products of combustion from every class of stove by means of a flue, if possible, or, where this actually cannot be attained, at least securing that, by good ventilation, there shall be no chance of an accumulation of these gaseous products.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

THE report has been issued of the commission appointed to inquire into the steps to be taken to bring into existence an institution which should form part of a teaching university for the Transvaal, and which should provide the highest training in the arts and sciences connected with mining and other industries. The commission recommends that, in establishing the proposed technical institute to form an integral part of a teaching university, simultaneous steps should be taken to lay the foundations of the university itself. Recommendations are made for the establishment of a permanent teaching institution and the acquisition of a site within a convenient distance of Johannesburg and Pretoria for a teaching university for the Transvaal, and for any other parts of South Africa which may wish to take part in the scheme. On this site should also be, besides the school of mines, the proposed agricultural school, the State laboratories for chemistry and animal and vegetable pathology. At the outset the appointment is recommended of a principal of the highest scientific attainments and proved organising capacity, with a salary of not less than 3000*l*. a year.

THE Columbia University of New York has, by an agreement with Mr. Joseph Pulitzer, undertaken to establish and conduct a school of journalism. President Eliot, of Harvard University, has proposed an outline for a practical scheme which details the subjects appropriate to a course